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Letter to the Editor

The future of nemertean taxonomy (phylum Nemertea) — a proposal

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Sundberg *et al.* (2016). The future of nemertean taxonomy (phylum Nemertea)–a proposal. *Zoologica Scripta 46*,

The species is the most practical biological unit for distinguishing habitats and the obvious first step in exploring biodiversity. Species are entities of generalization in biology, as all information gathered during different studies on individuals of a given species can be generalized for this species, but not for more inclusive taxa. The correct identification of previously named species, and the description and naming of new species, is thus a crucial and fundamental step not only just to describe the world's biota, but also to ensure that scientists are talking about the same entity. Taxonomic names are also needed to link species to data, produced by different researchers (or amateurs), so they can be related in various analyses – accurate name to data correspondence is becoming increasingly important in these times of growing and more accessible data bases. If data (e.g. ecological, morphological, molecular) cannot be linked to formal species and well-referenced names, these data will be tremendously diminished in value. Naming and description of species is thus essential, and here, we propose a new standard for describing nemertean (Nemertea) species that would facilitate this process.

Every taxonomic group has its own standard and culture when it comes to species descriptions, the part (together with the holotype) that connects a name with biological entity, the species. Some of these standards are consequences of the animals themselves — it is obviously easier, and possible, to base species descriptions on external characters in a group like Crustacea, while it is more problematic for taxa like Platyhelminthes that exhibit less external morphological complexity. But, differences in species description standards are also due to culture developed by active researchers for each taxon. When it comes to phylum Nemertea (nemerteans, ribbon worms), the current standard for a species description includes detailed accounts of external and internal characters, the latter only traditionally accessible through histological sectioning, although new techniques (like, e.g. confocal laser scanning microscopy in Chernyshev 2015) may change this picture in the future. Sundberg & Strand (2010) have pointed out problems with this approach, and here, we will only emphasize some main — as we see it — problems. First, histological sectioning is time-consuming and needs special equipment, competence and training. Shrinking research budgets in many academic departments have led to cuts in the number of technical staff, with a corresponding loss of competence and experience when it comes to histological work. Second, characters are often quite difficult to interpret from sections, and intraspecific variation furthermore confuses the taxonomic conclusions of the characters, something pointed out by Sundberg (1979). Strand *et al.* (2014) furthermore showed that morphological characters are not the panacea to good taxonomy as is often stated in nemertean literature. For example, one of the repeated statements is that nemerteans can only be securely identified from internal characters (see, e.g., Gibson 1985) or in the words of Roe *et al.* (2007: 221): 'Identification of most nemertean species is difficult and time-consuming, usually requiring study of internal anatomy by means of light microscopy on serial sections'.

Our common experience is, on the contrary, that external characters can identify many species, especially if you are working in a particular geographical area. Furthermore, we doubt that internal characters will help in difficult situations where there are groups containing species with similar external appearance, or in the cases of cryptic species. Even in good, valid, species, it may be difficult to find apomorphic internal characters (see, e.g., Envall & Sundberg 1993; Strand *et al.* 2005, 2014; Sundberg *et al.* 2009). We furthermore doubt that anyone will actually bother to section a specimen in order to identify it to species level when it comes to the identification of nemerteans in, for example marine surveys. Schander & Willassen (2005) showed that around 95% of the nemerteans in the samples were identified to just '*Nemertea* sp.' in the inventories they had surveyed, without mentioning any other taxonomic rank. Of course, examples of crypticism where a reliance on external features alone would be quite misleading also exist (e.g. *L. viridis*/*L. ruber* in Krämer *et al.* in press). Here, molecular evidence proves most efficient for distinguishing the species.

So, we conclude that internal characters are not, and will not, be used for identification and hence are not really needed when it comes to *identification* in biodiversity research questions. Internal characters will still be very useful in phylogeny estimates and for addressing a number of interesting biological questions about internal organ systems functionality and evolution, but should they be a formal requirement in species descriptions as currently often assumed? Currently, we face a situation where nemertean taxonomists over the world have many sampled specimens of new species waiting to be described and named. Considering the constraints pointed out above, we estimate that many of these species will remain undescribed unless we accelerate the pace of species description. Therefore, we as a group of researchers working on the group Nemertea have decided to accept species descriptions that will not meet the 'standard' of detailed accounts of internal characters as described above. If we do not transform the requirements, which are governed by tradition rather than empirical evidence, we are convinced that many species will remain undescribed and that this will lead to an underestimate of nemertean species diversity. It will also bias the geographical distributions of species, knowledge that could be useful not just for the taxonomists, but also for our understanding of global biodiversity. Similar approaches have already been successfully applied to other invertebrate groups, where species are described despite the lack of diagnosable morphological characters (Murphy *et al.* 2015).

We also want to approach the question of redescribing species. Many nemertean species are inadequately described, and it is often impossible to assign a sampled specimen to a particular name, due to poor descriptions and to the fact that types may not be available or properly preserved. In these cases, it is tempting to designate it as a new species, but we would encourage taxonomists to redescribe species if considered appropriate and justified. One question in that case is whether a redescription has to be based on a specimen from the type locality. Today, the main cost of taxonomy and systematics is associated with collecting specimens, and on top of that, there are collecting permit requirements that can be almost impossible to meet for some countries. We therefore suggest relaxing the condition of requiring specimens from the type locality and accepting specimens sampled in the vicinity of the locality. We understand that 'vicinity' is a vague concept, which relies on the individual researcher's judgement and competence.

Nemertean taxonomy in the future

We suggest that a species description should be considered acceptable if it contains all of the following:

- reference to DNA sequence(s) (considering the fast development in molecular techniques, we are not prepared to make a set decision of which molecular marker(s) to be used, currently COI is one preferred marker, but we also encourage authors to add more markers whenever possible)
- a description of the external characters (overview and detail colour photographs are highly desirable and essential for the description to be useful), including comments on the ecology of the species. In supplementary material, we suggest a checklist for what should be included.
- a holotype, and voucher specimen(s) preferably paratypes in ethanol, or another preservative (e.g. RNAlater® Ambion, Inc.) to ensure that DNA can be extracted.

We suggest that, when redescribing a species, the description is likewise acceptable if it includes:

- reference to DNA sequence(s), as above.
- reference to external characters, as above
- a neotype if no holotype available, and voucher specimen(s) in ethanol, or another preservative to ensure that DNA can be extracted

Although we argue that histology is not mandatory for describing a new species, we would like to encourage that, whenever possible, specimens from the same batch should be fixed for potential histological studies. Although these are not necessarily required for describing the new species, they offer the chance for future access to structural information pertinent for phylogenetic analyses and for understanding the evolution of the morphology of nemerteans and assessing organ function.

We finally argue that this approach might also be applicable to other soft-bodied invertebrates for which species identification is traditionally based on internal characters, but which feature distinct colour patterns, for example flatworms and nudibranchs. Due to the challenges of species identification, these taxa are often under-represented in data repositories (Kvist 2013). Species descriptions of these taxa also increasingly include DNA sequences and colour photographs (e.g. Lemos *et al.* 2014; Pola & Gosliner 2015), and thus, the modified taxonomic approach proposed herein for Nemertea will also provide useful for other groups.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Character checklist.

Supplementary material

Table S1. Character checklist

List of external characters that could be checked in order to provide a species description with comparable characters. Modified from Sundberg et al. (2009b), with some additions from Schwartz (2009).

	Character	Character state	Code
1.	Biology	Free-living	0
		Parasitic	1
		Commensal	2
2.	Habitat	Marine	0
		Freshwater	1
		Terrestrial/Semi-terrestrial	2
		Estuarine	3
3.	Benthic divisions (Nybakken&Bertness, 2004)	Supralittoral	0
		Littoral	1
		Sublittoral	2
		Bathyal	3
		Abyssal	4
4.	Pelagic divisions (Nybakken&Bertness, 2004)	Epipelagic	0
		Mesopelagic	1
		Bathypelagic	2
		Abyssopelagic	3
5.	Habitat	Interstitial	0
		Infaunal	1
		Epibenthic	2
		Epiphytic	3
		Epizoic	4
		Endozoic	5
6.	Substratum	Mud	0
		Sand	1
		Gravel/shell gravel	2
		Rock/boulders	3
		Macrophytes	4
		Other (e.g. in clams such in the case in *Malacobdella grossa*)	5
7.	Behavior when mechanically disturbed	Contracts without coiling into a spiral	0
		Contracts in a coiled spiral	1
		Contracts in a coiled spiral moving head back and forth	2
		Contracts into a knot	3
		Eversion of proboscis	4
		Production of copious volumes of mucus	5
		Spontaneous fragmentation	6
	External morphology		
8.	Cephalic furrows/slits	Absent	0
		One pair	1
		Two pairs	2
9.	Distribution of anterior cephalic furrows/slits	Ventral	0
		Dorsal	1
		Lateral	2
		Ventral and lateral	3
		Ventral and dorsal	4
10.	Shape of anterior (dorsal) cephalic furrows (viewed with tip of head directing forwards) (Figs 1, 2)	V-shape or oblique	0
		V-shape or oblique with secondary grooves	1
		Ventral transversal	2
		Lateral horizontal	3
		Dorsal (and ventral) longitudinal	4

11.	Shape of posterior (dorsal) cephalic furrows (viewed with tip of head directing forwards)	V/U-shaped or oblique	0
		Λ-shaped	1
	Constrictions at posterior of cephalic slits (Figs 1, 2)	Truncate	0
		Linear	1
		Rounded	2
12.	Head clearly demarcated from body	No	0
		Head wider than trunk	1
		Head not wider than trunk	2
13.	Position of cephalic furrows (Fig. 1)	If single pair behind brain lobes	0
		If single pair in front of brain lobes	1
		If two pairs, posterior pair behind brain lobes	2
		If two pairs, posterior pair in front of brain lobes	3
14.	Shape of head/cephalic lobe (Fig. 1)	Rounded	0
		Bluntly rounded	1
		Pointed	2
		Bluntly pointed	3
		Oval	4
		Spatulate	5
		Truncated	6
		Tapered	7
		Diamond-shaped	8
		Lancet-shaped	9
		Shield-shaped	10
		Bilobed	11
15.	Head viewed laterally	Without extensions	0
		Bilobed with ventral lobe further forward	1
		Flattened	2
		Flattened, “duck bill”	3
16.	Cross section shape of body	Rounded cylindrical	0
		Dorsal-ventrally flattened	1
17.	Shape of posterior tip	Pointed	0
		Bluntly pointed	1
		Rounded	2
		Bluntly rounded	3
		With caudal fin	4
		With caudal cirrus	5
		With caudal sucker	6
18.	Eyes (fig. 1)	Absent	0
		Two eyes near brain	1
		Two eyes on anterior tip of head	2
		Four eyes arranged at corners of square or rectangle	3
		Six eyes arranged in row of three at each side of head	4
		Three groups/rows of eyes on each side of head	5
		Four groups of eyes	6
		Eyes arranged in lateral rows or groups on each side of head	7
		Eyes irregularly distributed over head	8
		Two groups and one posterior eye on each side (cf. *Raygibsonia*)	9
19.	Eye distinctiveness	Eyes visible from ventral side	0
		Eyes not visible from ventral side	1
20.	Eye morphology	Simple	0
		Double	1
21.	Relative eye size (Fig. 1)	All eyes more or less of equal size	0
		Posterior pair/pairs distinctly larger	1
		Anterior pair/pairs distinctly larger	2
		Two or three pairs of more developed eyes and additional minute eyes	3
		Other	4
22.	Eye position relative to brain lobes	Confined principally or entirely to precerebral cephalic region but may extend back to above brain	0
		Extending behind brain lobes but confined to lateral dorsal body margins	1
		Extending behind brain lobes along dorsal and lateral body margins	2
23.	General body color	No obvious color	0
		Dark	1
		Pale / Light	2

24.	Primary dorsal body color	Red	0
		Green	1
		Yellow	2
		White	3
		Purple	4
		Brown	5
		Orange	6
		Pink	7
		Other	8
25.	Color pattern	Absent	0
		Confined to cephalic region	1
		Extending full body length on dorsal surface	2
		Restricted to post cephalic dorsal body surface	3
		On both dorsal and ventral body surfaces	4
26.	Color of blood	Red	0
		Green	1
		Brown	2
		Not applicable	3
27.	Proboscis armature	Absent	0
		As in *Callinera* (Kajihara, 2006)	1
		With central and accessory stylets	2
		With central stylet only	3
		With numerous small stylets on a cushion	4
28.	Number of accessory stylet pouches (H)	Two	0
		More than two	1
		Absent	2
29.	Number of stylets in each accessory stylet pouch (H)	One or two	0
		Three or four	1
		More than four	2
		Absent	3
30.	Stylet : basis/stylet ratio	1:1	0
		1,5:1	1
		3:1	2
		4:1	3
		1:1,5-2	4
31.	Stylet shaft	Smooth and straight	0
		Curved	1
		With helically arranged grooves	2
		With longitudinal grooves	3
32.	Shape of stylet basis	Oval (rounded)	0
		Pear-shaped	1
		Truncate	2
		Rod-shaped	3
		Cylindrical	4
		Falciform (Polystilifera)	5
33.	Median waist of stylet basis	Absent	0
		Present	1
34.	Proboscis used for locomotion	Unknown	0
		Yes	1
35.	Proboscis pore	Terminal	0
		Subterminal, ventral	1
36.	Position of mouth	Under brain	0
		Far behind brain	1
		Just behind brain	2
37.	Shape of mouth	Round	0
		Elongate slit	1
		Mouth not separate from proboscis pore	2
38.	Lateral margins	Appear paler than dorsal body surface	0
		No distinction in color	1
39.	Distribution of bristles/cirri	Not seen	0
		Only on head	1
		Only on tail	1

Figure 1. Nemertean head shapes, cephalic furrows, and eye distribution. A, rounded head, two pairs, anterior and posterior, cephalic furrows and eyes in rectangle (e. g. *Nemertopsis flavida*) ; B, buntly rounded head, eyes in square (e. g. *Oerstedia dorsalis*) ; C, pointed head (e. g. *Callinera monensis*); D, bluntly pointed head, anterior V-shaped and posterior L-shaped cephalic furrows. Also note the two eyes at the anterior tip of the head (e. g. *Amphiporus bioculatus*); E, head diamond-shaped (e.g. *Tetrastemma cephalophorum*); F, truncated head; G, head lancet-shaped (e. g. *Tubulanus inexpectatus*); H, oval head with anterior and posterior U-shaped cephalic furrows. Also note the eyes arranged in lateral rows on each side of head (e. g. *Amphiporus dissimulans*); I, head shield-shaped with secondary grooves of anterior cephalic furrows. Eyes as H (e. g. *Nipponnemertes pulchra*); J, head tapered-shaped (e. g. *Tetrastemma flavidum*); K, bilobed head, note the distinct anterior eyes (e. g. *Prosorhochmus claparedii*) (Redrawn from Gibson, 1974).

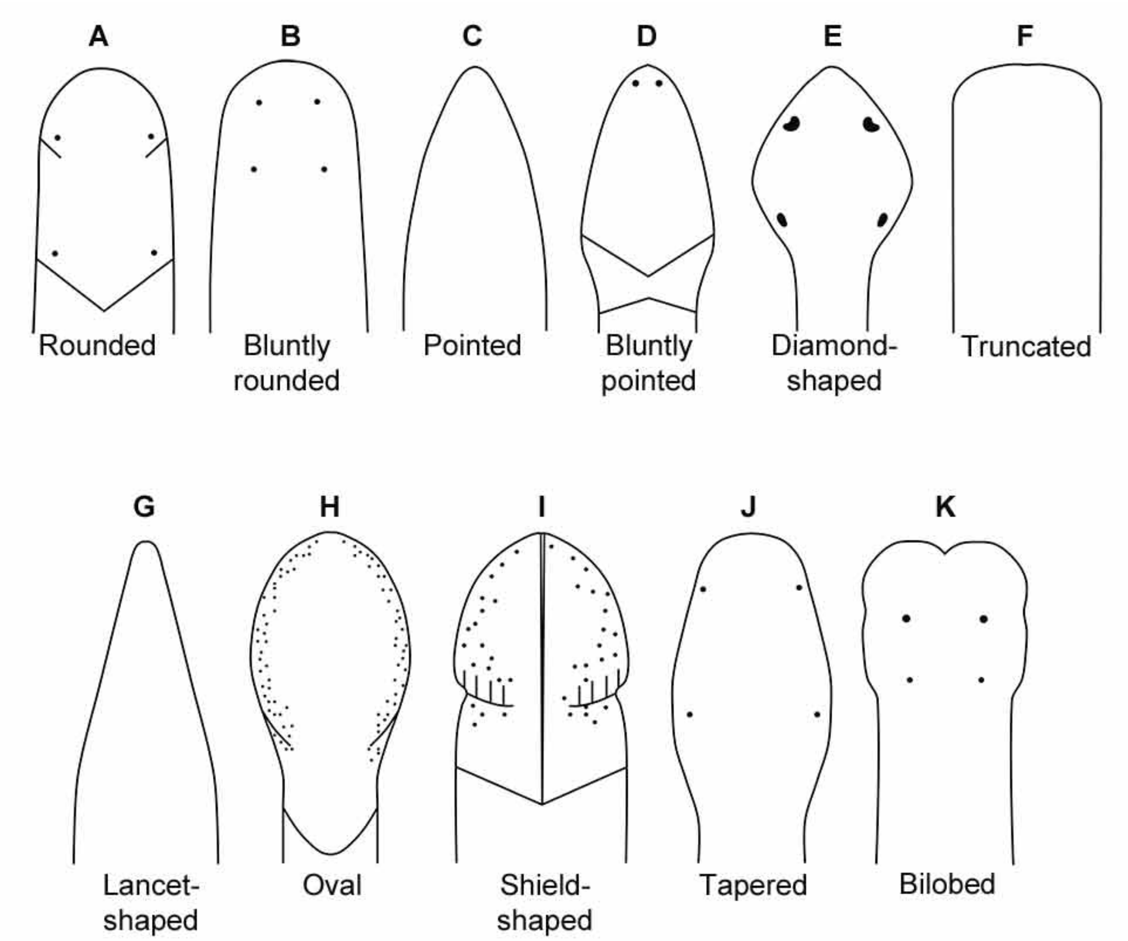
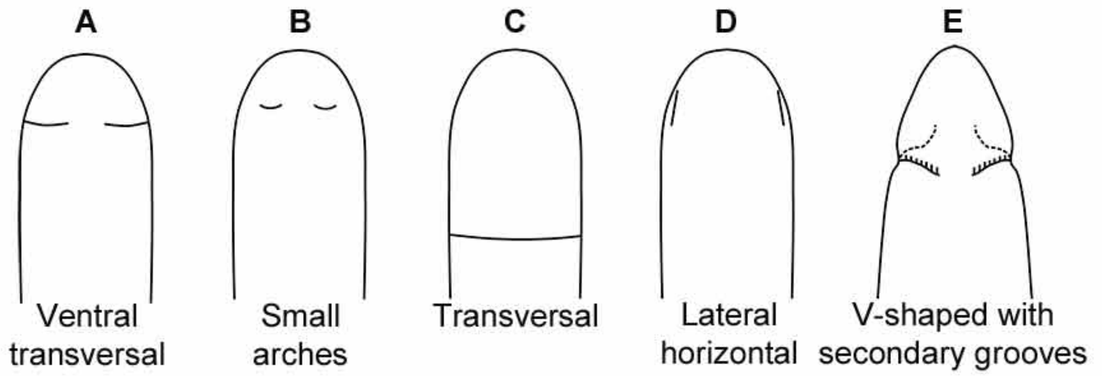


Figure 2. Schematic views of different cephalic furrows. A, ventral transverse furrows; B, small arches; C, posterior transverse furrow; D, lateral horizontal furrows; E, V-shaped furrows with secondary grooves (dashed lines show the ventral furrows).



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